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CO_2 Emission from Soil Containing Different Organic Manures in Wetting-Drying Conditions and the Relationships of CO_2 Emission with Moisture, Temperature and H_2O Emission

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Abstract: The aim of this study was to examine the effect of five different organic substance additions to the soil (hazelnut husk compost and farmyard, pigeon, poultry and sheep manures) on carbon dioxide (CO_2) emission from the soil and the relations of CO_2 emission with soil moisture, water steam (H_2O) emission and soil temperature during the wetting-drying cycle of the soil. The results showed that the highest CO_2 emissions was in pigeon manure treatment (0.805 g m^{-2} h^{-1}), and followed by hazelnut husk compost (0.658 g m^{-2} h^{-1}) and poultry (0.541 g m^{-2} h^{-1}), farmyard (0.476 g m^{-2} h^{-1}) and sheep manure (0.424 g m^{-2} h^{-1}) treatments and soil as control treatment (0.300 g m^{-2} h^{-1}), respectively. Soil moisture increased, and H_2O emission and soil temperature decreased in all organic substance treatments compared to the control (soil), thus the CO_2 emission had positive linear relationship with soil moisture and negative linear relationships with H_2O emission and soil temperature. Therefore, it could be concluded that it can be more protective opinion for global warming risk applying organic substances (sheep, farmyard and poultry manures respectively) with both low organic matter and nitrogen content to the soil by managing soil moisture to decrease CO_2 emission.

Keywords: CO_2 emission, H_2O emission, organic matter, soil moisture and temperature

Farklı organik gübre uygulanan topraklarda ıslanma-kuruma koşullarında CO_2 Emisyonu ve CO_2 Emisyonunun Nem, Sıcaklık ve H_2O Emisyonu ile İlişkileri

Öz: Bu çalışmanın amacı, toprağa beş farklı organik madde ilavesinin (fındık kabuğu kompostu ve çiftlik, güvercin, kümes hayvanları ve koyun gübreleri) toprağın ıslanma-kuruma döngüsü sırasında topraktan karbondioksit (CO_2) salınımına etkisini ve CO_2 salınımının toprak nemi, su buharı (H_2O) salınımı ve toprak sıcaklığı ile ilişkilerini incelemektedir. Sonuçlar, en yüksek CO_2 salınımının güvercin gübresi uygulamasında (0.805 g m^{-2} h^{-1}) olduğunu ve bunu sırasıyla fındık kabuğu kompostu (0.658 g m^{-2} h^{-1}), kümes hayvanları (0.541 g m^{-2} h^{-1}), çiftlik (0.476 g m^{-2} h^{-1}) ve koyun gübresi uygulamalarının (0.424 g m^{-2} h^{-1}) ve akabinden kontrol uygulaması olarak toprağın (0.300 g m^{-2} h^{-1}) takip ettiğini göstermiştir. Kontrol uygulamasına kıyasla tüm organik madde ilavesi uygulamalarında toprak nemi artmış, H_2O salınımı ve toprak sıcaklığı azalmış, böylece CO_2 salınımı toprak nemi ile pozitif lineer, H_2O salınımı ve toprak sıcaklığı ile negatif lineer ilişkiye sahip olmuştur. Bu nedenle, CO_2 salınımını azaltmak için toprak nemini yöneterek hem organik madde hem de azot içeriği düşük organik madde ilavelerinin (sırasıyla koyun, çiftlik ve kanatlı gübreler) toprağa uygulanmasının küresel ısınma riskine karşı daha koruyucu bir görüş olabileceği sonucuna ulaşılmıştır.

Anahtar Kelimeler: CO_2 salınımı, H_2O salınımı, organik madde, toprak nemi ve sıcaklık

1. Introduction

Organic fertilizer or organic matter additives to the soil significantly improve soil properties and provide positive advantages to crop production. Increasing organic matter in the soil improves the nutrient availability, cation exchange capacity, available water retention and all other productivity properties of the soil (Zhang et al., 2020). Oldfield et al. (2019) reported that because of increased organic matter in the soil, the crop's access to water and nutrients became easier, the strategy of regulating development and metabolic events increased, and organic matter also provided positive reflections on the yield and quality of the crop. In addition, mixing organic substances into the soil is also very important in terms of waste management and thus environmental sustainability (Powlson et al., 2012; Alaboz et al., 2021).

However, in addition to these positive reflections, there is a risk that organic matter contribution to the soil would increase the CO_2 emission from the soil. Depending on the protection of organic matter sequestration in the soil, the soil can be a reserve for CO_2

emission, or on the contrary, it can be a source of CO_2 emission (Yerli and Sahin, 2021). When organic carbon, which is an indicator of organic matter, cannot hold on to the soil, it turns into CO_2 when it encounters oxygen and spreads to the atmosphere (Yerli et al., 2019). The increased amount of organic carbon in the soil can accelerate the mineralization processes in the soil and increase the CO_2 emission, thus both soil and crop yields may be adversely affected due to the decreased organic carbon in the soil (Coban et al., 2015).

Since CO_2 has a share of 82% among greenhouse gases (Thangarajan et al., 2012), it has made the control of CO_2 emission a necessity in agricultural areas as well as in all areas. However, since there are many factors that stimulates CO_2 emission in agricultural soils, its management strategy becomes difficult. While factors such as soil moisture and soil temperature can affect CO_2 emission from the soil (Evans and Burke, 2013), soil properties are also effective in changing the direction of the CO_2 emission (Haddaway et al., 2016). In addition, the contribution of organic fertilizer or organic substance applied to the soil to increase the emission varies (Al-Kaisi and Yin, 2005). Depending on the organic matter and/or organic carbon and nitrogen content of the organic substance applied to the soil, the increase rate of CO_2 emission from the soil differs (Yerli and Sahin, 2021). Sainju (2002) explained this differentiation in relation to the fact that organic matter applied to the soil affect the microbial processes in the soil and thus change the oxidation.

There is little information regarding how much CO_2 is emitted from the soil from under wetting-drying process in the soil with different organic substances. Therefore, in this study, it has been hypothezed that CO_2 and H_2O emissions from soil and moisture-temperature conditions in soil would differ in the wetting-drying cycle of soil amended with different organic substance, and also that the CO_2 emission would be significantly affected by the soil moisture and temperature.

Thus, the effects of five organic manure additives with different properties on the soil moisture and temperature, CO_2 and H_2O emissions from the soil under the wetting-drying cycles of the soil, and the effects of soil moisture, H_2O emission and soil temperature on the CO_2 emission were investigated in this study.

2. Material and methods

The study was carried out in the laboratory of Van Yuzuncu Yil University, Faculty of Agriculture, Department of Biosystem Engineering with mean temperature of 24±2°C and humidity of 38±5% during the experimental period. The experiment was conducted with three replications using a completely randomized factorial design with 5 different organic substance addition (hazelnut husk compost and farmyard, pigeon, poultry and sheep manures) and soil as control treatment also.

While the hazelnut husk compost used in the study was prepared in the laboratory environment, farmyard, pigeon, poultry and sheep manures were obtained commercially and from farm areas. Prior to the experiment, some properties of hazelnut husk compost and farmyard, pigeon, poultry and sheep manures and the soil are made and presented in Table 1. The pH and EC values were measured by pH-meter and EC-meter in saturation extract, while total nitrojen and organic matter determined by Kjeldahl (Bremner and Mulvaney, 1982) and Walkley-Black (Nelson and Sommers, 1982) methods, respectively. Organic carbon was converted from the organic matter by a standard coefficient (Avramidis et al., 2015). Additionaly soil particle size distribution was analyzed by Bouyoucos hydrometer method (Gee and Bauder, 1986), and soil texture was defined as sandy-loam considering sand (66.3%), silt (15.6%) and clay (18.1%) contents.

Table 1. The properties of organic substances and soil used in the study
Çizelge 1. Çalışmada kullanılan organik maddelerin ve toprağın özellikleri

Properties	Soil	Hazelnut husk compost	Farmyard manure	Pigeon manure	Poultry manure	Sheep manure
pH	7.17	6.31	8.07	6.45	4.17	9.07
EC (dS m^{-1})	0.62	2.31	5.41	7.61	6.59	4.13
Total nitrojen (%)	0.04	1.35	1.22	4.31	1.73	1.61
Organic matter (%)	0.81	75.70	39.11	45.91	37.71	27.87
Organic carbon (%)	0.47	43.91	22.68	26.63	21.87	16.16

Sandy-loam soil, in air-dry form, sieved through a 2 mm sieve, was placed in 1.5 liter pots (diameter: 13 cm, height: 11 cm) after adding 1% organic matter addition treatments to the soil on a weight basis. To determine water amount retained at field capacity of organic substance treatments and control treatment, all pots were saturated with tap water, and covered with plastic film to prevent evaporation. Wet weights of the pots were determined by weighing when drainage stopped completely. Field capacity (pot capacity) was calculated from pot dry and wet weight, and soil bulk density (1.31 Mg m^{-3}). The field capacity values were 0.347, 0.332, 0.338, 0.331, 0.327 and 0.322 m^3 m^{-3} for hazelnut husk compost and farmyard, pigeon, poultry and sheep manure treatments and control treatment, respectively. Then all pots were incubated for three weeks at field capacity moisture before wetting-drying process was initiated. Before each irrigation carried out in the wetting-drying process, missing moisture determined by weighing was complated to weight in field capacity of each treatment.

EGM 5 gas analyzer device (CFX-2, PPSystems, Stotfold, UK) was used for CO_2 emission from soil measurement (Yerli et al., 2022a). While H_2O emission from soil measurement was performed automatically at the time of CO_2 emission measurement using the gas analyzer device, the measurement of soil temperature at 5 cm soil depth was provided with the STP-1 soil temperature probe connected to same the device simultaneously with the CO_2 emission measurement (Yerli et al., 2022b). Pots were weighed to determine soil moisture at the same time with the CO_2 emission measurement. All measurements were performed by taking daily measurements from each pot over three wetting-drying periods. The wetting-drying processes were applied totally three times with tap water irrigations of 7 days intervals in experiment period of three weeks.

SPSS program was used to valuate the obtained data. The data were evaluated by variance analysis (General Lineaar Model), and the Duncan multiple comparison test was performed for the significant means at the 0.05 level. Pearson correlation analysis was also applied to define the relationships of CO_2 emission with soil moisture, H_2O emission, and soil temperature.

3. Results and discussion

The effect of different organic substance treatments on soil moisture was found to be significant at the $P<0.01$ level (Figure 1). According to the control treatment, the soil moisture of hazelnut husk compost and farmyard, pigeon, poultry and sheep manure treatments were determined by 24.8%, 16.8%, 21.2%, 15.4% and 10.2% higher, respectively. This could be expressed as higher organic matter content increases moisture retention in the soil due to organic matter content directly affected the moisture balance in the soil (Alaboz and Cakmakci, 2020). The fact that soil moisture was obtained in a sequence depending on the organic matter content of the organic substances mixed (Table 1) supports this situation. This could be explained with the increased pore number and size, improved its distribution in the soil and the specific surface area of the soil from increased organic matter content (Yerli and Sahin 2021; Alaboz et al., 2022). Similarly, Yang et al. (2014) stated that organic matter mixed to the soil improves soil porosity and increases moisture retention in the soil. Ors et al. (2015) indicated that the soil moisture content is directly dependent on the pore size distribution, organic matter can improve the pore size distribution and resulting more water retention in soil. Altikat et al. (2018) also stated that increased manure amount increased soil moisture due to improved aggregation with increased organic matter content.

The effect of different organic manure treatments on H_2O emission was found to be significant at the $P<0.01$ level (Figure 2). According to the control treatment, the soil moisture of hazelnut husk compost and farmyard, pigeon, poultry and sheep manure treatments were determined by 4.1%, 8.0%, 11.9%, 9.9% and 8.0% lower, respectively. This could be expressed as high moisture retention in organic materials treatments (Figure 1) resulted in less H_2O emissions. Lal (2020) reported that organic matter has improves water retentiony of the soil, thus reducing the loss of H_2O from the soil. Yerli et al. (2022a) also indicated that because of increased moisture retention in the soil, H_2O emissions from soil decrease. Although soil moisture content was the highest in hazelnut husk compost, this treatment with higher H_2O emission compared to manure treatments might be increased evaporation from surface soil due to the increased soil pores connection probably based on aggregate size distribution in soil. Therefore, the high volume of the water absorbed the soil pores can be in subsurface soil layer in hazelnut husk compost treatment. Hussary et al. (2022) also indicated that the soil profile has the capacity to supply sufficient water to the surface as long as the fluid connections are maintained. H_2O emission also can be changed particle size decreases of organic matter, because organic matter decomposition as particle size decreases of organic matter decreases and hence results higher evaporation rates (Amooh and Bonsu, 2015).

The effect of different organic manure treatments on soil temperature was found to be significant at the $P<0.01$ level (Figure 3). According to the control treatment, the soil temperature of hazelnut husk compost and farmyard, pigeon, poultry and sheep manure treatments were determined by 2.4%, 4.5%, 6.6%, 5.4% and 4.4% lower, respectively. This could be explained by the soil cooling effect of higher moisture contents in organic substance added treatments (Figure 1). The soil thermal conductivity affected by soil moisture can change the heat capacity of the soil, leading to decreases in soil temperature with moisture increase (Yerli and Sahin 2021). Similarly, Licht and Kaisi (2005) reported that increased soil moisture decreased soil temperature. Mancinelli et al. (2015) also indicated a cooling effect of water applied on the soil with irrigation. In addition, Yerli et al. (2022b) stated that the soil temperature was determined to be lower in the conditions with high moisture as the effect of increased moisture in the soil. The high H_2O emisison in the hazelnut husk compost (Figure 2) may also support the temperature to be higher than the others due to the decrease in moisture on the surface soil.

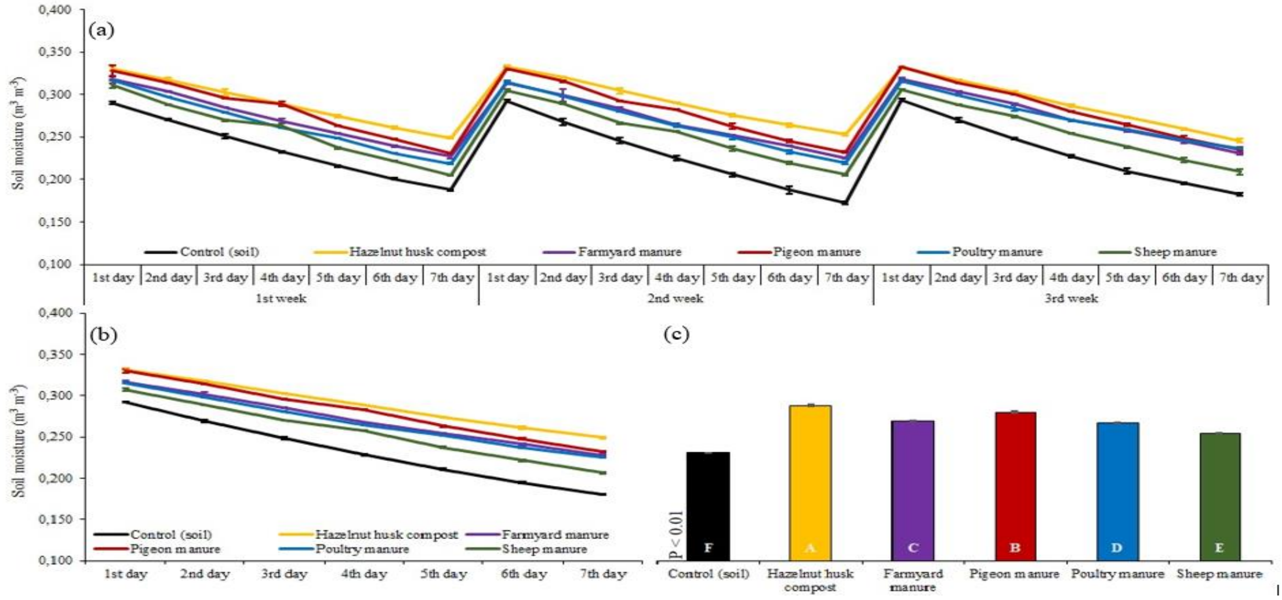

Figure 1. Soil moisture during the study period as daily (a), in the weekly mean as daily (b), and in the mean of all measurements (c)

Şekil 1. Çalışma süresi boyunca toprak neminin günlük (a), haftalık ortalamada günlük (b) ve tüm ölçüm ortalama değerleri (c)

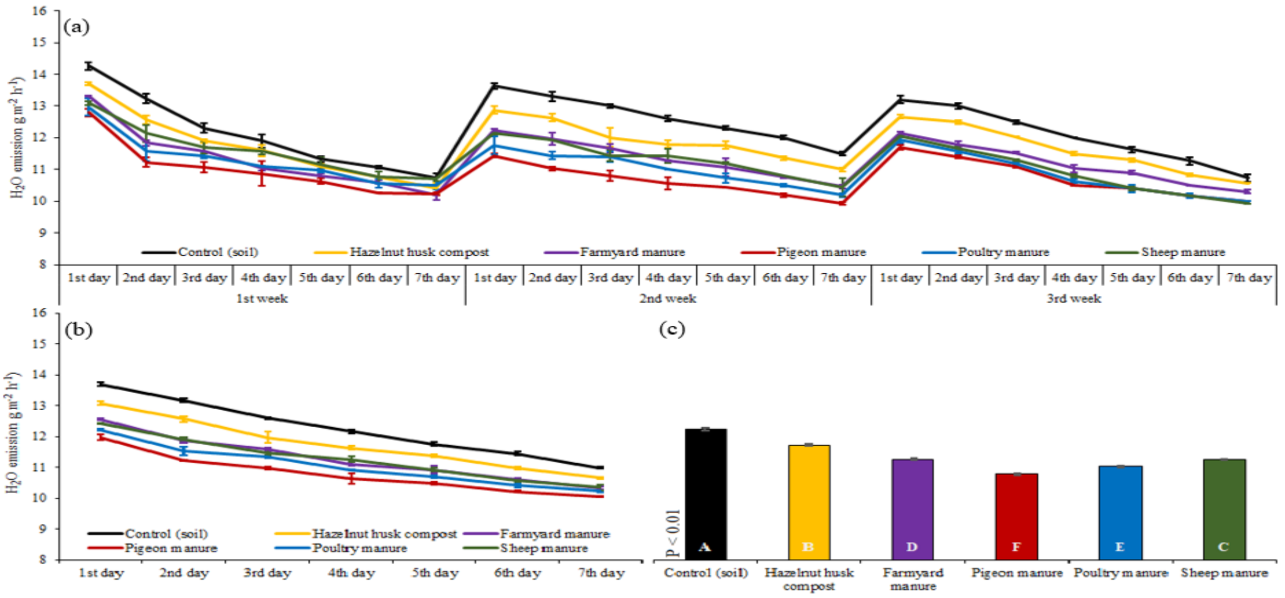

Figure 2. H_2O emission from soil during the study period as daily (a), in the weekly mean as daily (b), and in the mean of all measurements (c)

Şekil 2. Çalışma süresi boyunca topraktan H_2O salınımının günlük (a), haftalık ortalamada günlük (b) ve tüm ölçüm ortalama değerleri (c)

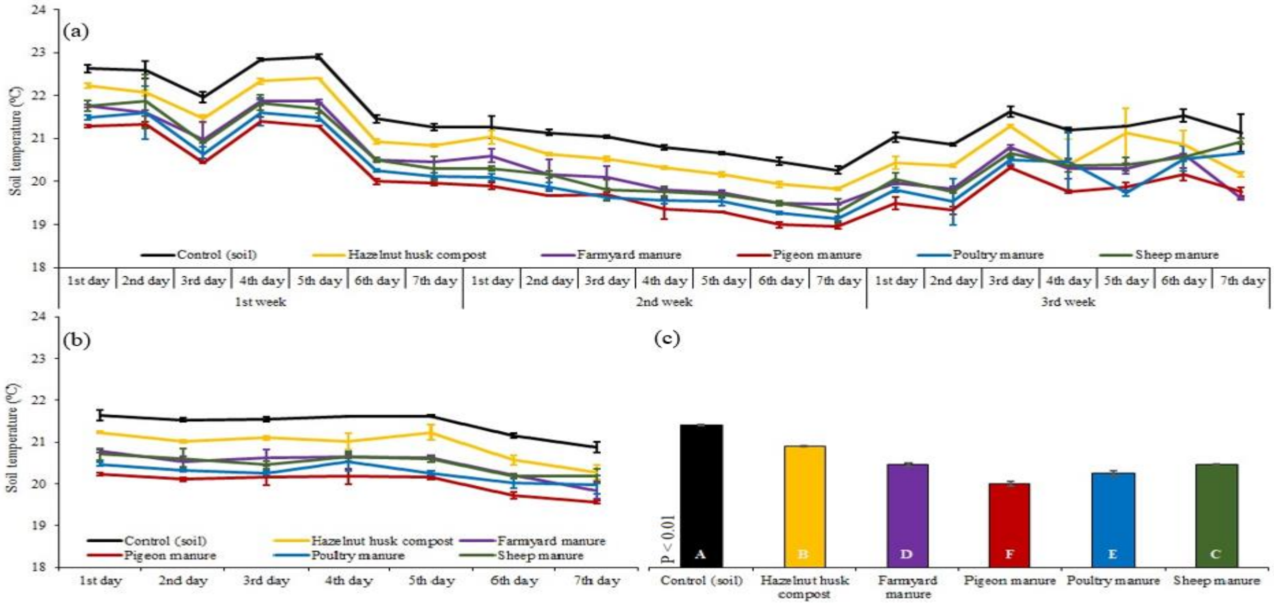

Figure 3. Soil temperature during the study period as daily (a), in the weekly mean as daily (b), and in the mean of all measurements (c)

Şekil 3. Çalışma süresi boyunca toprak sıcaklığının günlük (a), haftalık ortalamada günlük (b) ve tüm ölçüm ortalama değerleri (c)

The effect of different organic manure treatments on CO_2 emission from soil was found to be significant at the P<0.01 level (Figure 4). According to the control treatment, CO_2 emission from soil of hazelnut husk compost and farmyard, pigeon, poultry and sheep manure treatments were determined by 119.4%, 58.7%, 168.4%, 80.5% and 41.3% higher, respectively. Fangueiro et al. (2008) and Altikat et al. (2018) also stated that treatments of farmyard manure in the soil and increased amount of manure increases CO_2 emissions. Therefore, it could be expressed that the organic matter adding to the soil cause higher oxidation and increase the emission with high organic carbon and nitrogen content (Table 1). After the organic carbon in the soil passes through microbial processes, CO_2 emits when it combines with oxygen because of oxidation (Yerli et al., 2019). A higher amount of organic carbon entering the soil also increases the potential of CO_2 emissions (Yerli et al., 2022a). Nitrogen on the CO_2 emissions from the soil has also significant effect due to microorganisms need nitrogen during the oxidation process (Navarro-Pedreño et al., 2021). Therefore, increasing nitrogen in the soil increases soil biological activity and thus accelerates soil respiration because of oxidation (Tang et al., 2018). Sufficient soil moisture conditions also can be increased nitrogen oxidation and triggered CO_2 emissions from the soil (Yu et al., 2014). This showed that although, the hazelnut husk compost has 64.9% more organic carbon content than the pigeon manure (Table 1), the total nitrogen amount of the pigeon manure more than three times more than the hazelnut husk compost might have made it the treatment that caused the highest CO_2 emission. Hazelnut husk compost was the treatment with the second highest CO_2 emissions, and this might be related to its high organic carbon content (Table 1). Despite the close organic carbon contents of poultry and farmyard manures (Table 1), the higher total nitrogen content of poultry manure can be considered as the reason for its higher CO_2 emissions than farmyard manure treatment. The sheep manure treatment provided the lowest CO_2 emission due to the lowest organic carbon and total nitrogen content among the mixed substances (Table 1). Similarly, in a study in which different organic substances were mixed into the soil, it was stated that the CO_2 emission from the soil varies depending on the organic carbon and nitrogen content of the organic substance (Yerli and Sahin, 2021). In addition, it was reported that the EC and pH values of the organic manure applied to the soil are also important in the CO_2 emission from the soil due to its can effect microorganism activity (Sakin and Yanardag, 2019).

Many experimental studies of soil carbon dynamics focused soil temperature and moisture among the factors affecting soil organic carbon decomposition (Fang et al., 2022). The presence of moisture in the soil may increase the CO_2 emission as it affects the oxidation processes by affecting the soil biology (Yerli et al., 2022a). The significant positive linear relationship (P<0.01) of CO_2 emission with soil moisture determined in this study also strogly supported the reason of the emission (Figure 5). Therefore, as the effective stimulating factor for the higher CO_2 emission in different organic substance treatments compared to the control treatment (Figure 4) might be indicate higher soil moisture content (Figure 1). Moisture in the soil is an important factor in the mineralization of organic carbon and nitrogen (Shi ve Marschner, 2014). It is known that rewetting the dried soil triggers microbial activities and thus mineralization and then CO_2 emission (Lamparter et al., 2009). Li et al. (2010) stated that changing soil moisture with irrigation affects organic matter dynamics in the soil.

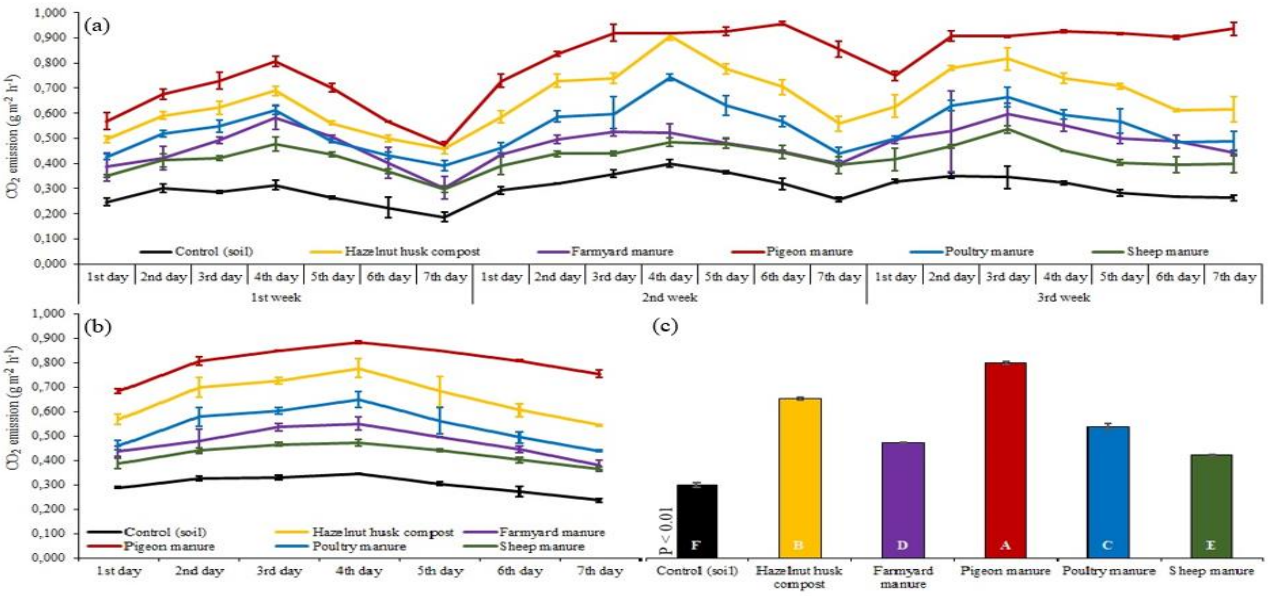

Figure 4. CO_2 emission from soil during the study period as daily (a), in the weekly mean as daily (b), and in the mean of all measurements (c)

Şekil 4. Çalışma süresi boyunca toprak CO_2 salınımının günlük (a), haftalık ortalamada günlük (b) ve tüm ölçüm ortalama değerleri (c)

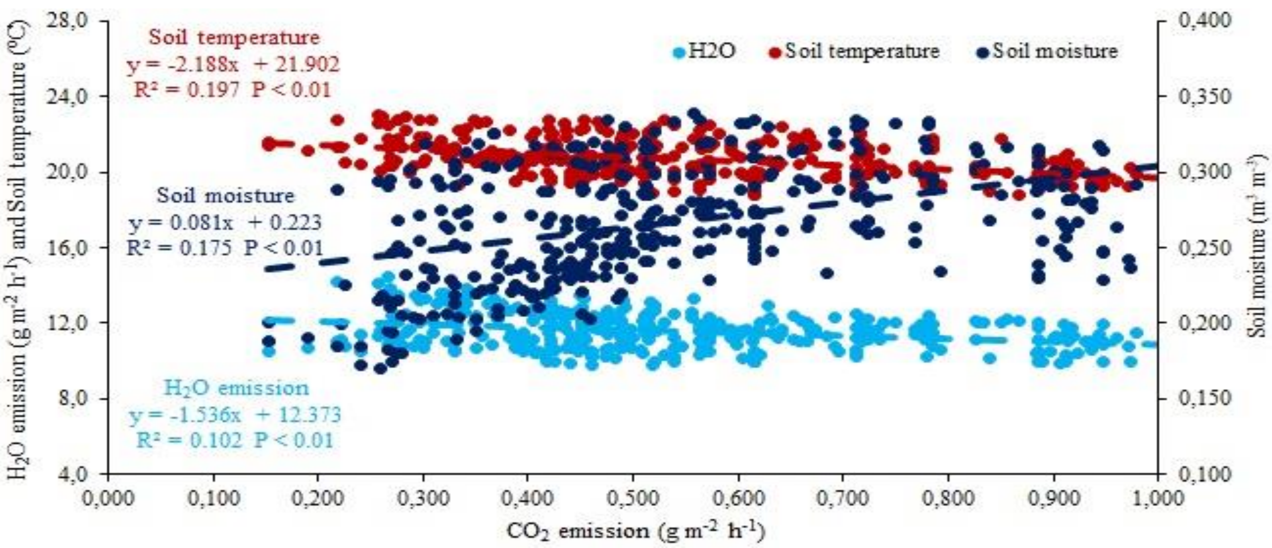

Figure 5. The relationships of CO_2 emission from soil with H_2O emission from soil and temperature and moisture in the soil

Şekil 5. Topraktan kaynaklanan CO2 emisyonu ile topraktan H2O emisyonu ve topraktaki sıcaklık ve nem arasındaki ilişkiler

Soil temperature is an important envirionmental factor in the mineralization of organic matter and nitrogen. Fan et al. (2021) reported that soil temperature has a significant effect on the population of soil microorganisms. Gonzalez-Mendez et al. (2015) stated that CO_2 emissions from the soil increased as a result of the acceleration of mineralization due to the increase in microorganism activity with increasing soil temperature. Jabro et al (2008) take attention to the correlation between CO_2 emission and soil temperature and reported that soil temperature increased CO_2 emission by 59%. On the contrary, the significant negative linear relationship ($P<0.01$) of CO_2 emission with soil temperature determined in this study (Figure 5). This shows that the effect of soil temperature on CO_2 emissions in moisture dominant conditions can change considering the cooling effect of moisture on the soil. Similarly, Buragiene et al. (2019) mentioned the negative linear relationship of CO_2 emission with soil temperature. Yerli et al. (2022b) reported the same result, and it was explained that negative linear relationship of CO_2 emission with soil temperature could be obtained under conditions that the effect of soil temperature on CO_2 emission is evaluated independently of soil moisture.

4. Conclusion

This study examined in the wetting-drying cycle of the soil, the effects of different organic substance additions to soil on CO_2 and H_2O emissions from soil and moisture-temperature conditions in soil and investigated the effects of soil moisture, H_2O emission and soil temperature on the CO_2 emission. It was determined that soil moisture increased, and H_2O emission and soil temperature decreased in all organic substance treatments, and the highest CO_2 emissions were in pigeon manure, hazelnut husk compost, and poultry, farmyard, and sheep manures, respectively. The CO_2 emission had positive linear relationship with soil moisture and negative linear relationships with H_2O emission and soil temperature. It could be concluded that it can be recommended to apply sheep manure to the soil for a more reasonable CO_2 emission compared to other organic substance treatments, and to keep soil moisture under management as an approach to reduce emissions, considering the effect of soil moisture on the emission. Therefore, it can be need to give priority to the studies that improving of this insight.

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